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ALDERFLY (NEUROPTERA: SIALIDAE) FLIGHT PERIODS, SEX RATIOS, AND HABITAT USE IN A VIRGINIA FRESHWATER TIDAL MARSH, LOW FOREST, AND THEIR ECOTONES

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Abstract.—Six Malaise traps, run from April 1998 through December 1999, obtained 3306 adult *Sialis iola* Ross (34% females) and one male *S. mohri* Ross in Dyke Marsh Preserve (DMP), Virginia. They flew from early April through early June. The abundance of *S. iola* significantly varied among a low forest, freshwater tidal marsh, and the forest-marsh ecotone, sometimes being significantly more common in the ecotone than other habitats. Malaise traps can be used efficiently to survey and monitor sialids in DMP and similar places. A thorough monitoring effort in the Preserve should include at least two traps in the three habitats and monitoring throughout sialid flight periods and the Preserve.

Key Words: Neuroptera, Sialidae, alderflies, flight periods, sex ratios, freshwater marsh, low forest

This study concerns sialids (Neuroptera: Sialidae, Alderflies) in a freshwater tidal marsh and adjacent low forest in the Mid-Atlantic region of the U.S.A. We provide information about adult sialid abundances and flight periods in three main habitats of Dyke Marsh Preserve (DMP), Virginia—low forest, freshwater tidal marsh, and the ecotone between them, based on Malaise-trap samples. The National Park Service (NPS) requires information on DMP species, their abundances, and their habitat uses, in order to manage the Preserve properly. A sialid study is particularly crucial at this time because Virginia may use a pesticide to control mosquitoes that carry the West Nile Virus. Such mosquito control could have marked deleterious effects on many DMP organisms.

Sialids can be abundant in aquatic and adjacent habitats where they are predators of other arthropods and food for vertebrates and other organisms including fish (Azam and Anderson 1969). Bowlker (1747) wrote in *The Art of Angling*, "the Orle Fly . . . is the best Fly to Fish with after the May Flyes are gone" (reference in the Oxford English Dictionary 1971). "Orle" is an old name for "alder."

There are 24 North American sialid species. Females lay egg masses of from about 200 through 900 eggs on objects over water such as bridges, culverts, and vegetation (Azam and Anderson 1969, Arnold and Drew 1987, Brigham 1982, Canterbury and Neff 1980). After hatching, the larvae fall into the water where they live under stones, vegetation, and other objects. Sialid larvae are aquatic predators of small aquatic insects (Pritchard and Leischner 1973). Fully developed larvae crawl out of the water onto land, and each forms an earthen cell

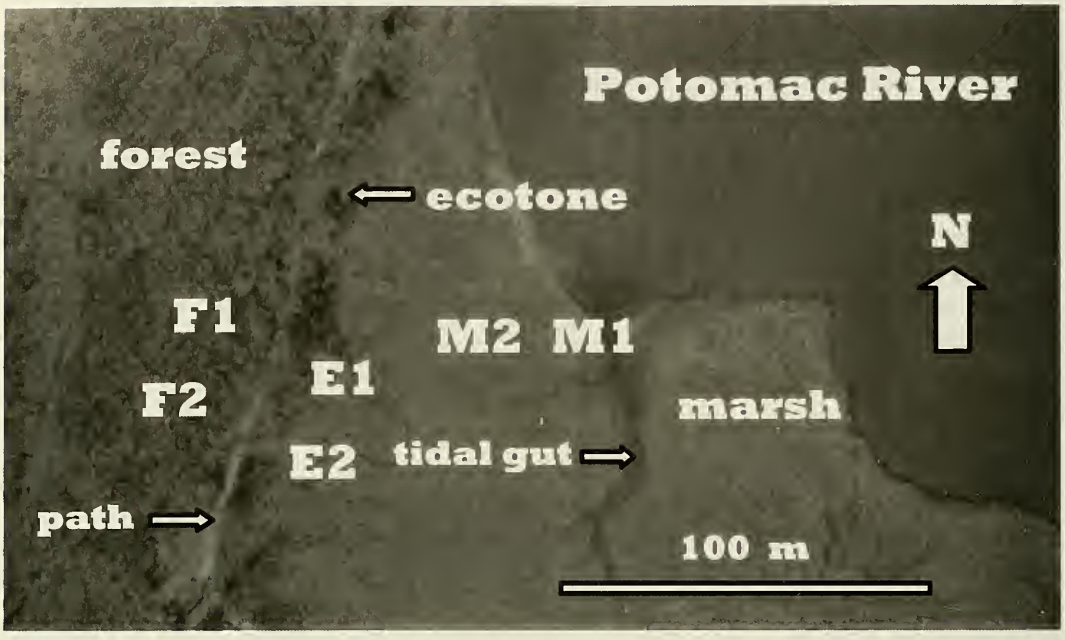

Fig. 1. Locations of the Malaise traps in Dyke Marsh Preserve, Virginia. E1 and E2 are positions of the ecotone traps; F1 and F2, forest traps; and M1 and M2, marsh traps.

in soil where it pupates (Ross 1937). Adults usually occur near water and live only a few days (Murnane 2004). Males are moderately fast fliers and more active during the day than at night. They have soft mouthparts and may not feed (Azam and Anderson 1969), or feed much, as adults (Ross 1937).

We report that our sampled sialids were over 99% *Sialis iola* Ross, a little-studied, abundant aquatic insect. They flew from early April through early June, and were markedly different in abundances and sex ratios among Malaise traps and habitats. Further we discuss the use of such traps for surveying and monitoring sialids.

Materials and Methods

We collected sialids in DMP from April 1998 through December 1999 using six Townes-style Malaise traps (Townes 1972) in Dyke Marsh Preserve (DMP), part of the George Washington National Parkway, Virginia, administered by the NPS (Johnston 2000). The 380-acre Preserve, on the western shore of the Potomac River in Fairfax County, Virginia, contains the largest remaining freshwater tidal marsh in the Washington, D.C., area (Johnston 2000). The Preserve has experienced marked degradation due to alien invasive organisms, shoreline erosion due to boat wakes and storms, and water pollution and associated harmful algal blooms.

Two traps were placed in each of three habitats—low forest, freshwater tidal marsh, and the ecotone between them (Fig. 1). The six traps were in a broad transect that ran east and west. The ecotone (defined as 10 m on each side of the forest-marsh edge) ran about 200 m approximately north-northeast and south-southwest in our sampling area. We oriented each trap so that its longitudinal axis ran east and west and its collecting head faced due east. The forest traps were about 50 m west of the ecotone, and the marsh traps averaged about 60 m east of the ecotone. Forest trap 1 (F1) was about 30 m north-northeast of forest trap 2 (F2), ecotone trap 1 (E1) was about 30 m north-northeast of ecotone trap 2 (E2), and marsh trap 1 (M1) was about 30 m east

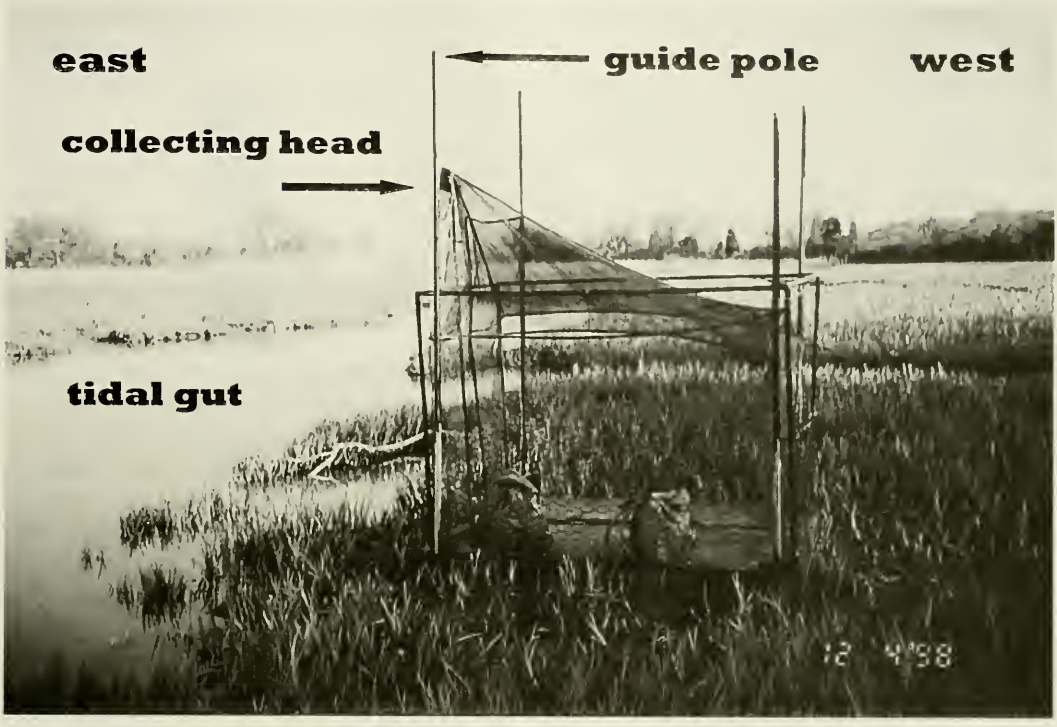

Fig. 2. A buoyant Townes-style Malaise trap in the marsh at low tide, 12 April 1998. Two backpacks are temporarily on the trap's base.

of marsh trap 2 (M2). The ecotone traps were in the edge of the open marsh (where they usually experienced about 0.3 m of water during high-tide periods) and were about 3 m from the edge of the forest. The mid-point location of the forest traps is 38.77194°N 77.05083°W; ecotone traps, 38.77139°N 77.05056°W; and marsh traps, 38.77172°N 77.04990°W.

Each trap was 1.2 m wide, 1.7 m long, 1.0 m high at its back and 2.0 m high at its front, the location of its collecting head (Fig. 2; Barrows and Kjar, 2005; keyword: Malaise trap, images of our study traps in each habitat). Each trap had 1-mm^2 mesh, nylon gauze; 61-mm wide, black crab-cage wire; a supporting metal frame; and a collecting head. We spray-painted trap gauze and supporting frames black in an attempt to decrease their visibility to sialids and human park visitors. The crab-cage wire encircled the base of each trap and prevented objects such as snapping turtles and driftwood from tearing trap gauze. Each trap was mounted on a floating platform, 1.2 by 1.8 m, that rose up to 1 m when the tide entered the Preserve's marsh. Vertical metal poles kept traps in place as they moved up and down. Forest traps were not buoyant because their forest sites did not flood during our study period, but can flood as high as 2.6 m during hurricanes. Sialids flew or crawled into the top part of a trap's collecting head, and then became entrapped in its bottom part filled with 95% ethanol. All traps ran during our entire 21-month sampling period, except the marsh traps. We removed them from late December 1998 through late March 1999, because possible flooding during that time could have destroyed them.

Sialid samples are from five intervals in 1998 (5 April–6 June) and four intervals in 1999 (11 April–6 June). We did not find sialids in our samples during other sampling periods.

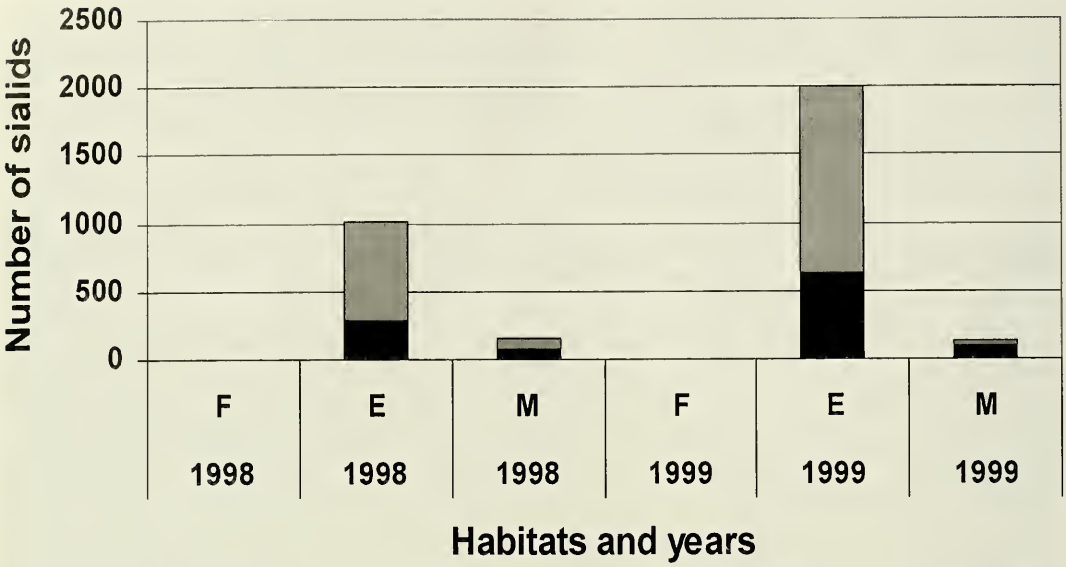

Fig. 3. Both female and male *Sialis iola* were more common in the ecotones than in the other habitats in both years. Black parts of the bars represent females; gray parts, males. The forest traps had one female and one male in 1998 (which are not shown on the graph) and no sialids in 1999.

To look for possible differences in the number of sialids per day among habitats, we used repeated-measures analysis of variance (ANOVA) and the Student-Newman-Keuls test (SPSS, Inc. 2003). To look for possible differences between observed sex ratios and expected 1:1 sex ratios within a habitat or interval, we used Preacher's (2003) online Chi-square test program.

Results and Discussion

Traps obtained 3307 sialids comprising 3306 *Sialis iola* and one male *S. mohri* Ross during our 2-yr study. The *S. mohri* was from a sample from 12–28 April 1998 from an ecotone trap. Our traps were in a limited area of the Preserve, and we do not know whether *S. mohri* is rare throughout the Preserve. The sialids that were previously know from the Washington, D.C., area (defined as Montgomery and Prince Georges counties, Maryland; Arlington and Fairfax counties, Virginia; and Washington, D.C.) are *Sialis aequalis* Banks (which is known from MD and VA), *S. americana* (Rambur) (DC, MD), *S. infumata* Newman (MD, VA); *S. iola* Ross (DC, MD), *S. itasca* Ross (DC, MD, VA), *S. joppa* Ross (MD), *S. vagans* Ross (VA), and *S. velata* Ross (DC, MD, VA) based on Ross (1937), Flint (1964), Tarter et al. (1978), Whiting (1991), and material in the collection of the National Museum of Natural History, Smithsonian Institution. *Sialis mohri* was previously recorded from Minnesota through New Brunswick south though New Jersey and Pennsylvania in eastern U.S. and south through Tennessee, Mississippi, Arkansas, and Oklahoma in central U.S., but not from Virginia. *Sialis iola* was not previously known from the Washington, D.C., area.

There were 1,168 *S. iola* in the samples in 1998 and 2,138 in 1999. The observed yearly differences in this species' abundance might be the result of natural fluctuations in its population size. Both females and males were most common in the ecotone compared to the marsh and forest based on raw data from 1998 samples, 1999 samples, and 1998 and 1999 samples combined (Fig. 3). The 1998 males and the 1999 females were significantly more common in the ecotone than the forest or marsh

Table 1. The number of females, males, and both sexes combined varied among habitats based on Malaise-trap samples from Dyke Marsh Preserve, Virginia.*

Group	1998		1999		Combined *P*	
	F	*P*	*F*	*P*	*F*	*P*
Females + males	8.312	0.060	6.345	0.084	10.581	≤0.010
Females	4.220	0.134	162.765	0.001	17.835	≤0.001
Males	11.970	0.037	2.708	0.213	9.687	≤0.010

* The degrees of freedom for all repeated-measures ANOVAs is 2. We combined probabilities using the process described by Sokal and Rohlf (1969).

(Table 1, $P \leq 0.05$, repeated-measures ANOVA and Student-Newman-Keuls test). The statistical analyses may have not found other actual differences in abundances among habitats, because of large abundance variances of trap samples within a habitat. Females alone, males alone, and both sexes combined showed significantly different abundances among the three habitats when the *P* values of both years were combined (Table 1).

Sialis iola flew from April through early June in both years (Figs. 4a, b), a shorter span than that recorded for the entire range of the species which is 1 April through 29 July (Tarter et al. 1978, Whiting 1991). In 1998, the number of females peaked in the samples of 10–17 May and 17–26 May, and the number of males peaked in the sample of 12–28 April. In 1999, both females and males were most common in the sample of 9–23 May. Flight periods suggest that *S. iola* was protandrous in both years.

Sampled sex ratios of *S. iola* were significantly male biased in 1998, 1999, and both years combined (Table 2). This bias may be due to an actual preponderance of males in the Preserve, or, if this species has a true 1:1 adult sex ratio, a greater tendency for the traps to catch males rather than females. As in other species, *S. iola* males may fly more than females and, therefore, be more likely to be trapped than females. For example, in two western U.S. species, *Sialis californica* Banks and *S. rotunda* Banks, adult males are more active than females and swarm near vegetation along shores and walk up and down plants (Azam and Anderson 1969). Females are usually heavily egg-laden and have considerably restricted flight. A female might be highly likely to oviposit in, or very near, the particular area where she was a larva. The sampled sex ratios of *Sialis iola* were significantly male-biased in the ecotone but not in the marsh in 1998, 1999, and both years combined (Fig. 3, Table 2). If there is a 1:1 sex ratio in new marsh adults, the ecotone male-biased samples suggest that many males leave the marsh and search for females in the ecotone. Further because the marsh sex ratio is female-biased, on the average, each marsh male competed with fewer other males for mates.

In conclusion, we report that DMP sialids flew from early April through early June, and their abundances markedly varied among traps and habitats. We obtained baseline data on DMP sialids with the view of monitoring and managing them in the future. Malaise traps are an excellent means to monitor them because the traps can be run 24 hours per day, and these traps can collect large samples of sialids for detailed analysis. Malaise traps often obtain rare species that might be missed by visual censusing and hand collecting and other collecting means. Our data indicate that it would be most efficient to trap sialids in the ecotone, if limited resources would not permit sampling other habitats as well. Sample sizes from traps of the same style, which are contemporaneously run in the same habitat, can markedly vary. In 1998–1999, one ecotone trap had 34% more sialids than the other, and one marsh

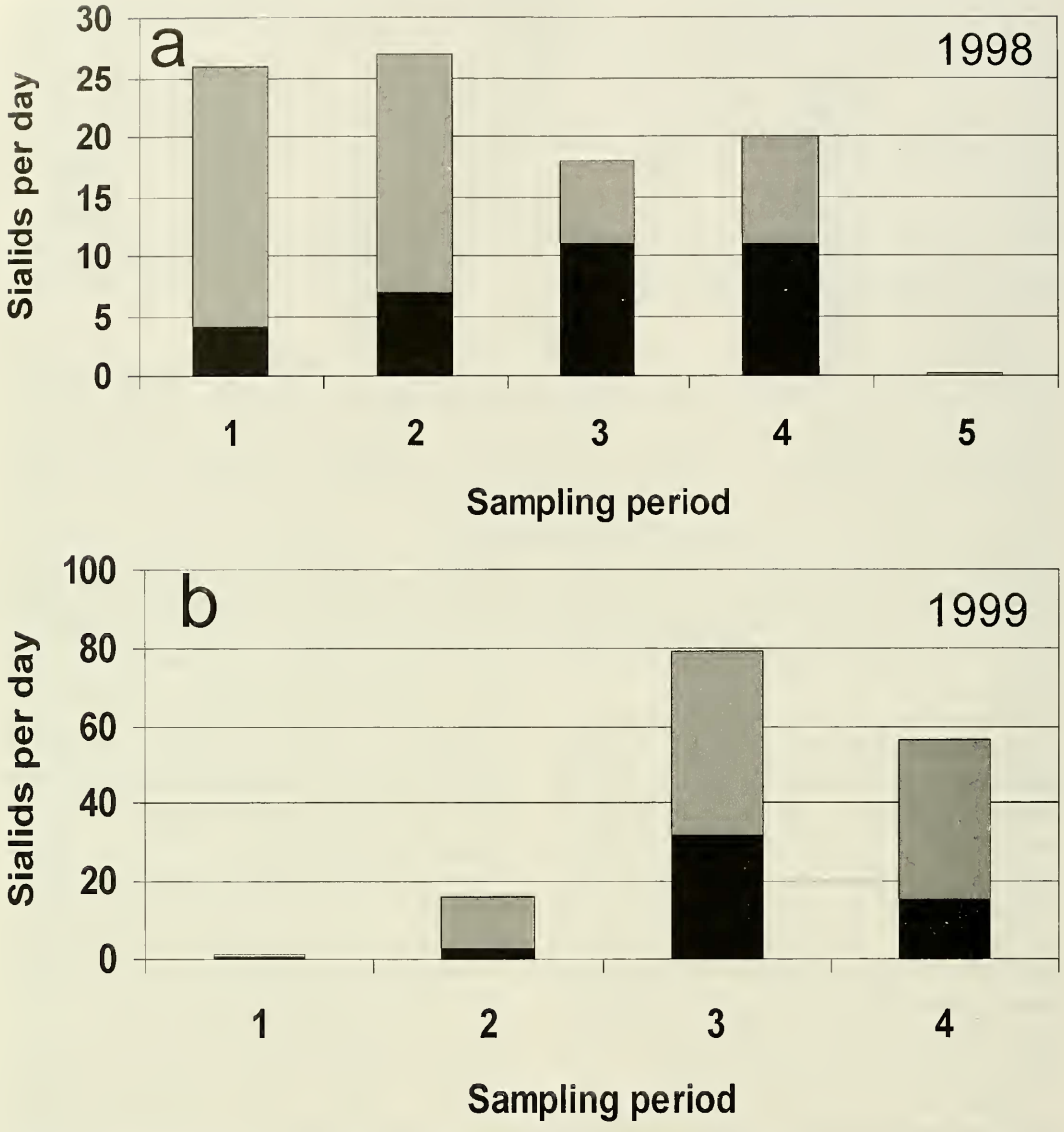

Fig. 4. Male *Sialis iola* were more common earlier in the flight season than females. Black parts of the bars represent females; gray parts, males. 4a, The 1998 collecting periods are 1 (12–28 April), 2 (28 April–10 May), 3 (10–17 May), 4 (17–26 May), and 5 (26 May–6 June). The traps had 0 female and 0.1 male per day in period 5. 4b, The 1999 periods are 1 (11–25 April), 2 (25 April–9 May), 3 (9–23 May), and 4 (23 May–6 June). The traps had 0.4 female and 0.7 male per day in period 1.

trap caught 67% more than the other. Therefore, monitoring should use at least two traps. More traps per habitat would provide an even more complete picture of sialid abundances from year to year than two traps. To understand sialid annual population fluctuations and species composition better, it would be worthwhile to monitor them for at least 10 years with Malaise traps, hand-collecting, and other appropriate means throughout the Preserve. The high abundance of sialids in the ecotone indicates the great value of this habitat with its woody plants for these animals.

Table 2. The sex ratios of *Sialis iola* were significantly different from 1:1 in the ecotone and usually in the marsh based on Malaise-trap samples from Dyke Marsh Preserve, Virginia.*

Year	Habitat	No. of Sialids	% Females	X^2	P
1998–1999	All three	3,606	32.7	395.9	<0.0001
	Ecotone	3,016	30.3	468.0	<0.0001
	Forest	2	50.0	—	—
	Marsh	288	57.6	6.7	0.0095
1998	All three	1,168	30.9	170.3	<0.0001
	Ecotone	1,020	27.5	207.5	<0.0001
	Forest	2	50.0	—	—
	Marsh	146	54.8	1.3	0.2467
1999	All three	2,138	33.7	227.9	<0.0001
	Ecotone	1,996	31.8	265.5	<0.0001
	Forest	0	—	—	—
	Marsh	142	60.6	6.4	0.0118

* P values are from Chi-square tests in which the expected sex ratios were 1:1 in a particular habitat within year. The forest samples were too small for Chi-square analysis.

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